AN ATTEMPT TO CORRELATE THE MITRAL VALVE ECHOGRAM WITH THE HEMODYNAMICS OF PATIENTS WITH PURE MITRAL INSUFFICIENCY

HYONGI KIM, MASAHIKO KINOSHITA, YOSHINORI SHIRAHAMA,
GO TOMONAGA, REIZO KUSUKAWA,[†] AND SHIGETAKE SASAYAMA^{††}

Echocardiographic, hemodynamic and angiocardiographic studies in 11 patients with pure mitral insufficiency were carried out with special reference to the correlation of the amplitude of motion of the anterior mitral valve with total stroke volume, regurgitant volume, regurgitant percent and ejection fraction respectively, and of the descent rate of the anterior mitral valve with total stroke volume, mean mitral valvular flow during diastole and Ry/v respectively.

The characteristic findings of mitral valve echogram in mitral insufficiency were the increase in amplitude rather than the increase in the descent rate of the anterior mitral valve. On the basis of echocardiographic findings patients with mitral insufficiency were classified into three groups.

The increase in amplitude may be assumed due to the increase in total stroke volume, but no correlation was found between total stroke volume and amplitude, while positive correlation between amplitude and ejection fraction was found. Positive correlation between the descent rate of the mitral valve echogram and Ry/v was found.

From these results it is suggested that one of the factors affecting the descent rate is elasticity of left atrium and that one of the factors affecting amplitude is total stroke volume corrected for left ventricular end-diastolic volume (ejection fraction).

AN INCREASE in the amplitude and the descent rate of the anterior mitral valve echogram has been previously described as a diagnostic abnormality of pure mitral insufficiency.¹ But clinically on many occasions there arise difficulties in finding the typical pattern of the

mitral valve echogram as have been described previously. The reason may be as follows: 1) the difference in the pathology of the mitral valve (rheumatic origin, rupture of the chordae tendineae or papillary muscle dysfunction, etc.) 2) the difference in the hemodynamics (regurgitant volume, total stroke volume and compliance of the left ventricle and left atrium, etc.) In the study on eleven patients with pure mitral insufficiency we attempted to correlate the various hemodynamic parameters with the echographic findings in the recumbent position to see how the motion of the anterior mitral valve reflects the hemodynamic phenomena.

Key Words: Echocardiography
Mitral Insufficiency
Angiocardiography
Total Stroke Volume
Ejection Fraction
Ry/v
Amplitude of Motion of the
Anterior Mitral Valve
The Descent Rate of Anterior
Mitral Valve

(Received for publication, January 31, 1973)

[†] Department of Cardiology, Tenri Hospital, Tenri City, Japan

^{††} His present address is the 3rd Medical Clinic, Kyoto University Hospital, Kyoto

* The outline of this report was presented in the Panel Discussion at the 22nd Meeting of the Japan Ultrasound Society, Miyazaki, November 24, 1972.

Fig.1. This figure illustrates the method of calculating Ry/v and presents pre- and postoperative Ry/v and EDR of one case in Group I with pure mitral insufficiency due to the rupture of anterior chordae tendineae.

METHODS AND MATERIALS

The patient material studied will be reported

under two sections. Section I of the study was concerned with diagnostic evaluation of the amplitude and the descent rate of the anterior

Fig.2. This figure illustrates comparison of the amplitude and EDR in 17 patients with pure mitral stenosis, 12 with myocardial infarction, 11 with pure mitral insufficiency and 33 normal subjects. Amplitude and EDR of patients with pure mitral insufficiency are scattered in comparison with the others.

mitral valve echogram and included as follows: 33 normal subjects with an age range of 12 to 60 (mean 23 years), 17 patients with pure mitral stenosis and 12 patients with acute and chronic myocardial infarction without complicating mitral insufficiency. Section II was concerned with an attempt to correlate the amplitude and the descent rate of the mitral anterior cusp with the hemodynamic parameters in eleven patients with pure mitral insufficiency; 6 cases due to rheumatic fever, 4 cases due to rupture of chordae tendineae, and 1 case of congenital origin.

All of these patients had the following examinations: after standard right heart catheterization was completed in the resting state, left heart catheterization was performed in retrograde fashion via the femoral artery by Seldinger's method or by incision of the femoral artery, and cardiac output was measured by Fick principle. After pressure recordings were completed, 30 to 40 ml of contrast material were injected into the left ventricle by means of the Gidlund power injector. Biplane angiograms (6 frames/sec) by Elma Schönander film changer or cine angiograms (50 frames/sec) were taken.

Electrocardiogram and X-ray exposure signs were recorded simultaneously at a paper speed of 10 cm per second. End-diastolic (EDV) and end-systolic volume (ESV) of the left ventricle were calculated as previously reported². Regurgitant volume (RV) and regurgitant percent (R%) were calculated by $TSV - \text{effSV}$; and $100(TSV - \text{effSV})/TSV$ respectively, where TSV represents total stroke volume and "eff SV" effective stroke volume respectively. Ejection fraction (EF) and mean mitral valvular flow during diastole were calculated by TSV/EDV and $TSV/\text{diastolic period}$ respectively.

Pure mitral insufficiency was confirmed by detecting no difference between end diastolic pressure in left ventricle and left atrium.

RY/v was calculated from the pressure of pulmonary artery wedge or left atrium by Owen and Wood's method³ as shown in Fig. 1. All tracings were measured for five successive beats and the mean value was calculated.

Ultrasound records were obtained with ALOKA SSD 3 type utilizing a 2.25 MHz transducer with a repetition rate of 1,000 per second by the ultrasonic "B" mode display,

TABLE I DATA OF HEMODYNAMICS AND MITRAL VALVE ECHOGRAM IN PURE MITRAL INSUFFICIENCY

	S. I.	J. W.	S. I.	K. M.	T. I.	K. H.	M. U.	Y. M.	K. M.	F. W.	E. W.
Age & Sex	46 m	46 m	41 f	21 f	38 f	24 m	23 m	31 m	62 f	46 f	41 m
B.S.A. (m ²)	1.46	1.52	1.25	1.57	1.36	1.68	1.47	1.70	1.54	1.63	1.75
C.T.R. (%)	77	67	56	54	55	50	45	68	66	67	68
Rhythm	a. f.	a. f.	RSR	RSR	RSR	RSR	RSR	a. f.	a. f.	RSR	a. f.
Remarks	died	Ope.	Op. died					Ope.	Ope.		
C.O. (L/min)	4.6	7.1	3.8	7.4	8.6	8.34	7.71	4.32	2.5	3.78	4.55
Pressures											
L.V. (mmHg)	128/0-22	100/4-10	104/0-14	100/5-11	114/0-10	118/0-18	100/0-6	100/0-14	134/0-18	138/0-24	137/-18
p.c. wedge	v38 26	v42 22	v78 28	v15 11	v11 7	v20 14	v13 7	v20 15	v24 17	v59 32	v42 27
P.A.	47/20	54/20	72/32	28/10	25/7	30/12	18/8	34/18	37/23	80/29	56/24
Ry/v	2.0	6.0	4.41	3.75	5.20	2.5	4.4	1.04	4.90	4.44	4.42
Volumes											
L.V. VED	(cine) 182	(cine) 214	(cine) 279	(bipl.) 266	(cine) 252	(cine) 226	(bipl.) 155	(bipl.) 426	(cine) 247	(cine) 278	(cine) 206
VES	87	66	82	83	53	47	65	214	98	35	90
T.S.V.	95	148	192	183	199	179	90	212	149	243	116
Ej, Fr.	52	69	70	69	79	79	58	50	60	87	56
S.V. (ml)	53	88.6	42	104	80	108	75	73	34	47	76
R.V. (ml)	42	59	150	79	119	71	15	139	115	196	40
R.P. (%)	44	40	78	43	60	40	16	66	71	81	35
dist. mitral val. flow/sec	399	569	468	435	948	325	360	589	281	769	580
Amplitude of mit. val. echo	33	40	28	36	41	45	30	36	34	43	41
E.D.R. (mmHg)	58	332	162	110	178	326	125	48	180	175	241

Fig. 3. UCG patterns of mitral insufficiency.

(with simultaneous electrocardiogram).

The transducer was placed in the third, fourth or fifth intercostal space close to the left sternal border and the ultrasonic beam was aimed at the anterior leaflet of the mitral valve.

For measurements of amplitude and E point descent rate (EDR) the tracings with the large-amplitude of movement were used. The E point represents the mitral cusp at its most anterior position and EDR represents the rate of posterior movement of the anterior leaflet of the mitral valve after the anterior movement associated with opening of the valve.⁴ The velocity represented by the diastolic slope is expressed in millimeters per second. The amplitude (Amp) of the mitral valve echo represents the entire anteroposterior excursion of the anterior leaflet of the mitral valve.⁴

In atrial fibrillation, five presentations with minimal R-R interval of 0.55 to 1.2 second⁵ were taken and the mean value was calculated.

RESULTS

The EDR from the records of 33 normal subjects ranged from 70 to 270 mm/sec with a mean of 164 mm/sec. (Fig. 2) The total amplitude of the movement of the anterior mitral leaflet varied from 22 to 32 mm with an average of 27 mm. (Fig. 2)

In pure mitral insufficiency the EDR ranged from 48 to 332 mm/sec with a mean of 176 mm/sec (Table I) and the total amplitude ranged from 28 to 45 mm with a mean of 37 mm. (Table I) On the basis of echocardiographic findings of mitral valve motion eleven patients were classified into three groups as shown in Fig. 3 and summarized as follows:

Group I; 2 cases	Amp. incr. (over 32 mm) EDR incr. (over 270 mm/sec)
Group II; 7 cases	Amp. incr. or normal (over 22 mm) EDR normal (70–270 mm/sec)

Fig.4. Correlation of ejection fraction with amplitude and EDR.

Symbols for Figs.4 to 9.

● Amplitude

Δ EDR

Fig.5. Correlation between Ry/v and EDR.

Group III; 2 cases Amp. incr. or normal (over 22 mm)

EDR decr. (under 70 mm/sec)

Fig.6. Correlation of total stroke volume with amplitude, and EDR, respectively.

Fig.7. Correlation of regurgitant volume with amplitude, and EDR, respectively.

The results of hemodynamics and ultrasound-cardiogram in eleven patients with pure mitral insufficiency are presented in Table I.

No definite correlation was found between ejection fraction and EDR ($r=0.48$, $p>0.05$), but positive correlation was found between ejection

Fig. 8. Correlation of regurgitant percent with amplitude, and EDR, respectively.

Fig. 9. Correlation of mean mitral valvular flow with amplitude, and EDR, respectively.

fraction and amplitude ($r=0.54$, $p<0.05$) as shown in Fig. 4.

Positive correlation was noted between Ry/v

and EDR with $r=0.48$ ($p>0.01$) as shown in Fig. 5.

No correlation was found between Ry/v and

Amp. ($r=0.06$, $p>0.05$) No correlation was found between EDR and TSV ($r=0.02$, $p>0.05$), RV ($r=-0.15$, $p>0.05$), R% ($r=-0.18$, $p>0.05$) and mean mitral valvular flow ($r=0.01$, $p>0.05$) respectively as shown in Figs. 6, 7, 8, 9.

No correlation was found between Amp. and TSV ($r=0.38$, $p>0.05$), RV ($r=0.12$, $p>0.05$), R% ($r=-0.02$, $p>0.05$), and mean mitral valvular flow ($r=0.44$, $p>0.05$) respectively. (Figs. 6, 7, 8, 9)

DISCUSSION

The observations of several investigators attest the sensitivity of the ultrasound technique in detecting normal and abnormal motion of the anterior mitral leaflet. In normal subjects EDR varied from 70 to 210 mm per sec.^{1,6-9} In comparison with these data we found normal values from 70 to 270 mm/sec. Two subjects whose EDR was over 210 mm/sec were 14 and 16 years old and the reason was thought due to the hyperkinetic state at puberty. In the presence of pure mitral insufficiency or congenital abnormalities with a high flow across the mitral valve, EDR of normal or more rapid than normal dimension has been reported in previous studies.^{1,10-12}

Eleven patients with pure mitral insufficiency were classified into three groups by the findings of EDR and amplitude. Most of the patients belonged to Group II (normal EDR, and increased or normal amplitude). The two cases of Group I (increased EDR and amplitude) had the typical mitral valvular echogram of mitral insufficiency. Clinically one (J.W.) had a rupture of the anterior chordae tendineae in the middle portion verified at operation. The other patient had had subacute bacterial endocarditis complicating rheumatic mitral insufficiency. Both had small atria, high pulmonary artery wedge pressure and Ry/v values. On the other hand, two patients of Group III (decreased EDR, and normal or increased amplitude) had severe mitral regurgitation with the syndrome of large atrium and normal left atrial and pulmonary arterial pressures as originally described by Braunwald.¹³

Winters¹⁴ demonstrated that diminished amplitude is related to increasing calcification of the mitral valve.^{15,16} The high amplitude of mitral valvular echogram of both patients of Group III suggests little organic change in the mitral valve. One was operated and no fusion of the chordae was noted but shortening and thickening of the posterior mitral valve was detect-

ed.

Roberts¹⁷ summarized mitral insufficiency hemodynamically as follow: the majority of patients with mitral regurgitation fall somewhere between the following two extremes; one has a large atrium with normal left atrial pressure and the other has a small atrium with high left atrial pressure. This point of view coincides with our classification of mitral insufficiency on the basis of our mitral valve echographic findings.

EDR may be influenced by various factors; 1) character of the mitral valve 2) velocity of blood flow through the mitral valve 3) compliance of left atrium 4) compliance of left ventricle¹⁸⁻²² 5) pressure difference between left atrium and left ventricle.¹⁸ EDR is supposed to reflect these hemodynamic factors if the valve is intact. Of our eleven cases of pure mitral insufficiency, 6 cases had had rheumatic fever, but by varying the sensitivity of the apparatus, the valve was shown to be thin in intensity, and the echo low, suggesting a noncalcified structure.

Failey²³ demonstrated that Ry/v ratio is influenced by the atrial size and by the elastic property of the atrial wall. The positive correlation between EDR and Ry/v may reflect one factor of compliance of the left atrium.²⁴ The patients with less compliant small left atria have higher values of Ry/v and increases in EDR, the ones with more compliant, large left atria have lower values of Ry/v and a decrease in EDR.

Nine of eleven patients with pure mitral insufficiency had increased amplitude and it follows that a feature of the mitral valve echogram in pure mitral insufficiency may be an increase in amplitude rather than an increase in EDR.

Sweatman²⁵ reported that the most frequently exhibited indices of mitral regurgitation due to ruptured chordae tendineae are an increase in amplitude and a greater incidence in the posterior leaflet. But four of our eleven cases had ruptured chordae tendineae; 3 cases were rupture of the anterior chordae and 1 case was of the posterior chordae, verified at operation. One of the three cases of rupture of the anterior chordae did not demonstrate any increase in amplitude. (Amp 27 mm)

Wharton²⁶ suggested an amplitude over 30 mm is in part due to dilatation of the left ventricle. But our data showed no correlation between EDV and amplitude. ($r=0.05$; $p>0.05$)

Chakorn²⁷ suggested that increased left ventricular stroke volume is likely to be the cause of

increased amplitude. Although we agree with Chakorn conceptually,^{18,28,29} our data did not show any correlation between amplitude and TSV. ($r=0.38$, $p>0.05$) But unexpectedly positive correlation between amplitude and EF was noted. It may be suggested that standerization to left ventricular volume could be done by dividing TSV with EDV. It follows that the increase in EF may be a reflection of hemodynamic factors causing the increase in amplitude of pure mitral insufficiency.

Positive correlation between amplitude and EDR^{30,31} in myocardial infarction uncomplicated by mitral insufficiency ($r=0.78$, $p<0.01$) as shown in Fig. 2 suggests that mitral valve movements reflect closely homodynamics when the valves are intact.

While the number of cases studied is not large enough to make a definitive statement, a continuing attempt to correlate mitral valve echograms of the same etiology without organic change is desirable to determine how the mitral valve reacts to various hemodynamic factors.

SUMMARY

The amplitude and the descent rate of mitral valve echogram were correlated with hemodynamic parameters in eleven patients with pure mitral insufficiency. The following results were obtained.

- 1) Positive correlation was found between EDR and Ry/v
- 2) Positive correlation was found between amplitude and EF.
- 3) No correlation was found between EDR and TSV, RV, R%, EF and mean mitral valvular flow respectively.

Acknowledgement

The authors are grateful to Mr. K. Masuda for his devoted technical assistance.

REFERENCES

1. SEGAL, B. L., LIKOFF, W., & KINGSLEY, B.: Echocardiography: Clinical application in mitral regurgitation. *Amer. J. Cardiol.* 19: 50, 1967.
2. SASAYAMA, S., KUBO, S., & KUSUKAWA, R.: Hemodynamic and angiocardigraphic studies on cardiodynamics. Experimental mitral insufficiency. *Jap. Circul. J.* 34: 518, 1970.
3. OWEN, S. G. & WOOD, P.: A new method of determining the degree or absence of mitral obstruction. *Brit. H. J.* 17: 41, 1955.
4. EDLER, I.: The diagnostic use of ultrasound in heart disease. *Acta Med. Scand.* (Suppl. 308) 32, 1955.
5. GARRARD, C. L. Jr., WEISSLER, A. M., & DODGE, H. T.: The relationship of alterations in systolic time intervals to ejection fraction in patients with cardiac disease. *Circulation* 42: 455, 1970.
6. JOYNER, C. R., REID, J. M., & BOND, J. P.: Reflected ultrasound in the assessment of mitral valve disease. *Circulation* 27: 503, 1963.
7. WINTERS, W. L., RICCETTO, Jr., & SOULEN, R.: Assessment of reflected ultrasound as a diagnostic instrument in the study of mitral valve disease. *Brit. Heart J.* 29: 788, 1967.
8. EDLER, S.: Mitral valve function studied by the ultrasound echo method, in Grossman, C. C., Holmed, J. H., Joyner, C., and Purnell, E. W., editors: *Diagnostic ultrasound*, New York, 1966, Plenum Press, pp.198-228.
9. EFFERT, S.: Pre- and postoperative evaluation of mitral stenosis by ultrasound. *Am. J. Cardiol.* 19: 59, 1967.
10. EDLER, I. & GUSTAFSON, A.: Ultrasonic cardiogram in mitral stenosis. *Acta Med. Scand.* 159: 85, 1957.
11. ULTAN, L. B., SEGAL, B. L., & LIKOFF, W.: Echocardiography in congenital heart disease. Preliminary observations. *Am. J. Cardiol.* 19: 74, 1967.
12. GUSTAFSON, A.: Correlation between ultrasound cardiography, hemodynamics and surgical findings in mitral stenosis. *Am. J. Cardiol.* 19: 32, 1967.
13. BRAUNWALD, E. & AWE, W. C.: The syndrome of severe mitral regurgitation with normal left atrial pressure. *Circulation* 27: 29, 1963.
14. WINTERS, W. L. Jr., HAFER, J. Jr., & SOLOFF, L. A.: Abnormal mitral valve motion as demonstrated by the ultrasound technique in apparent pure mitral insufficiency. *Am. Heart J.* 77: 196, 1969.
15. JOYNER, C. R. Jr., DYRDA, I., BARRET, J. S., & REID, J. M.: Preoperative determination of the functional anatomy of the mitral valve. (Abstr.) *Circulation* 32 (Suppl. II): II-120, 1965.
16. SCHMITT, W. & BRAUN, H.: Ultraschallkardiographische Vergleichsuntersuchungen bei Mitralstenosen. *Med. Welt* 12: 571, 1965.
17. ROBERTS, W. C., ROSS, R. S., & MASSUMI, R. A.: Chronic mitral regurgitation of unresolved etiology in the elderly. *Johns Hopkins Med. J.* 122: 26, 1968.
18. ZAKY, A., NASSER, W. K., & FEIGENBAUM, H.: Study of mitral valve action recorded by reflected ultrasound and its application in the diagnosis of mitral stenosis. *Circulation* 37: 789, 1968.
19. DUCHAK, J. M. Jr., CHANG, S., & FEIGENBAUM, H.: The posterior mitral valve echo and the echocardiographic diagnosis of mitral stenosis. *Amer. J. Cardiol.* 29: 628, 1972.
20. MOREYRA, E., KLEIN, J. J., SHIMADA, H., & SEGAL, B. L.: Idiopathic hypertrophic subaortic stenosis diagnosed by reflected ultrasound. *Amer. J. Cardiol.* 23: 32, 1969.
21. PRIDIE, R. B. & OAKLEY, C. M.: Mechanism of mitral regurgitation in hypertrophic obstructive cardiomyopathy. *Brit. Heart J.* 32: 203, 1970.
22. SHAH, P. M., GRAMIAK, R., & KRAMER, D. H.:

- Ultrasound localization of left ventricular outflow obstruction in hypertrophic obstructive cardiomyopathy. *Circulation* 40: 3, 1969.
23. FAIRLEY, K. F.: The influence of atrial size and elasticity on the left atrial pressure tracing. *Brit. Heart J.* 23: 512, 1961.
 24. REMINGTON, J. W.: Introduction to muscle mechanics, with a glossary of terms. *Fed. Proc.* 21: 954, 1962.
 25. SWEATMAN, T., SELZER, A., & COHN, K.: Echocardiographic diagnosis of mitral regurgitation due to ruptured chordae tendineae. *Circulation* 36: 580, 1972.
 26. WHARTON, C. F. P. & BESCOS, L. L.: Mitral valve movement: a study using an ultrasound technique. *Brit. Heart J.* 32: 344, 1970.
 27. CHAKORN, S. A., SIGGERS, D. C., & DEUCHAR, D. C.: Study of normal and abnormal movements of mitral valve ring using reflected ultrasound. *Brit. Heart J.* 34: 480, 1972.
 28. FEIGENBAUM, H., ZAKY, A., & NASSER, W. K.: Use of ultrasound to measure left ventricular stroke volume. *Circulation* 35: 1092, 1967.
 29. ZAKY, A., GRABHORN, L., & FEIGENBAUM, H.: Movement of the mitral ring: Study in ultrasound cardiography. *Cardiov. Res. (London)* 1: 121, 1967.
 30. WINTERS, W. L., RICCETTO, A., & SOULEN, R.: Reflected ultrasound as a diagnostic instrument in study of mitral valve disease. *Brit. Heart J.* 29: 788, 1967.
 31. TALLURY, V. K., DePASQUALE, N. P., & BURCH, G. E.: The echocardiogram in papillary muscle dysfunction. *Amer. Heart J.* 83: 12, 1972.